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A Comparison of Efficiency with Productivity Criteria for European Container Ports *

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Contents

Abstract

The shipping industry and the transportation of goods through ports have been rapidly growing owing to global economy, containerization of different types of goods, state of the art ship construction technology, and efficient logistics networks. As a nation's major infrastructure for international trade, porthas become important in its role as a connecting point between land and sea transportation. In global logistics environment, stiff competition among major ports worldwide to dominate and control the container market will get more intense.Therefore, ports strive to improve the service and facilities to attract more ships from across the world. As of 2008, more than 80% of international trade is done by sea transport and to meet the growing demand for goods transport, ports need to expand their capacity by improving the productivity of ports facilities. In this regard, this study focuses on the evaluation and comparison of port efficiency with 4 productivity criteria based on which the overall ranking will be determined. For the research, we employed PROMETHEE method to calculate the rank of the 19 European container ports.

The result shows that the GioiaTauro, Valencia, and Rotterdam ports scored the first 3 ranks in the year 2010, respectively. The Rotterdam has the highest productive working hours but lowest productivity in crane utilization. Valencia has 2 criteria (berth, area) with the highest productivity but relatively longer working hours considering the throughput. GioiaTauro shows 69% or higher in 3 criteria(berth, area, crane) with the highest crane productivity, whereas the working hour is only 18% in productivity. Based on the result of the study, Rotterdam needs to take some measure to utilize the crane in more efficient way, while Valencia, and GioiaTauro require more flexible working hours in the direction of reducing the overall working hours of employees.

Key words : Productivity, PROMETHEE, container ports, efficiency

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I. Introduction

Since the 1980s, the thrust of globalization has propelled the growth of the shipping industry and the global seaborne trade. More than 80% of international trade in goods is being carried by sea transport, accounting for more than 8.17 billion tons in 2008 (UNCTAD, 2009).[1)]

As the demand for international trade and global logistic services continues to increase, substantial investments and improvements in both physical capacity and operational efficiencies are necessary to enhance terminal productivity. To meet growing demand, ports need to enhance capacity. Pure physical expansion is constrained by a limited supply of available land, especially for urban center ports, and escalating environmental concerns. In this context, expanding port capacity by improving the productivity of terminal facilities appears to be the only viable solution.[2)]

In this study, we employ the PROMETHEE (preference ranking organization method for enrichment evaluation) method, one of the multi criteria decision making methods, to measure the efficiency of 19 top European ports using productivity and determine the overall rank of the ports. The productivity of the ports is defined as the ratio of output to input, where output is throughput(TEU) and inputs are berth length, number of container cranes, terminal area, and hours of working.

In general, many of the studies for efficiency of ports have been focusing on the efficiency of ports considering multi input and output variables using the DEA (Data Envelopment Analysis).

DEA is a technique for measuring the relative efficiencies of homogeneous decision-making units that use similar inputs to produce similar outputs where the multiple inputs and outputs are incommensurate in nature. For theoretical work on ports, many empirical studies have used DEA to measure technical efficiency of ports.[3)]

To assess the port efficiency, suitable input and output variables should be selected first, to apply the DEA technique. For input variables, berth length, number of berths, terminal area, number container cranes, labor, and capital are commonly used while for output variables, customer satisfaction,

1) Munisamy(2011).
2) Hanh(2006).
3) Munisamy(2011).

number of ships, and container throughput, among others, are most employed factors. Son[4] summarized the input and output variables used for efficiency calculation in various studies. However, with the DEA, due to the relative efficiency among ports, multiple number of ports can be appointed as efficient making it difficult to classify the more efficient ports even at the same level of efficiency. For an application of different techniques to container ports refer to Ha and Park.[5]

Hanh[6] used multipleproductivitycriteria to show the efficiency among ports and mentioned how to improve the productivity. However, the overall rank for ports was not explicitly identified, for they comparedthe ports on a criterion by criterion basis.

On the other hand, the PROMETTHEE developed by Brans&Vincke[7] is a non-parametric outranking method, to rank the alternatives in the order or preference using multiple criteria to be considered. For each alternative, positive(leaving) and negative(entering) preference flows are calculated based on preference function. The positive flow represents the degree of domination of a given specific alternative over all the other alternatives, while the negative flow expresses the degree of being dominated by the other alternatives.

The PROMETHEE has been studied in a variety of decision making problems having multiple criteria and developed in more complex combination with different techniques. Shirinfar and Haleh[8] used the Fuzzy PROMETHEE in supplier selection problem. Resumen[9] used integer linear programming method based on the result of PROMETHEE to choose the distribution centers of a firm in Belgium among 12 alternatives. Mohagar et.al[10] also applied the linear programming model for supplier outsourcing problem. Athawale et.al[11] applied PROMETHEE for the selection of logistics plant location with 8 criteria. Wang et.al[12] used fuzzy PROMETHEE for a bank in Taiwan to select the outsourcer in IT industry. Kara[13] used the combination of Fuzzy AHP and PROMETHEE to select supplier in Turkey.

4) Son(2010).
5) Ha(2010) ; Park(2009) .
6) Hanh(2006).
7) Brans et.al(1985).
8) Shirinfaret. Al(2011).
9) Resumen(2004).
10) Mohagar et.al(2011).
11) Athawale et.al(2011).
12) Wang et.al(2008).
13) Kara(2011).

Tuzkaya[14)] used combined model with AHP to select the environment friendly mode of transportation for the freight delivery. Jati[15)] also used the AHP for the selection of teacher in vocational schools. Eshlaghy et.al[16)] summarized the methods used for researches over the period of 1999-2009 for multiple criteria decision making problems.

In spite of various applications of PROMETHEE, there are, to the best of author's knowledge, few studies focusing on efficiency of ports under the productivity criteria. Therefore, in this study using 4 productivity criteria the overall outranking of 19 European ports are calculated with PROMETHEE.

The remainder of the study is organized as follows: In section II general procedure to implement the PROMETHEE is summarized and the analysis of 19 European ports is conducted based on the selected input and output data in section III. Finally, the conclusion and future research direction are mentioned in section IV.

II. PROMETHEE method

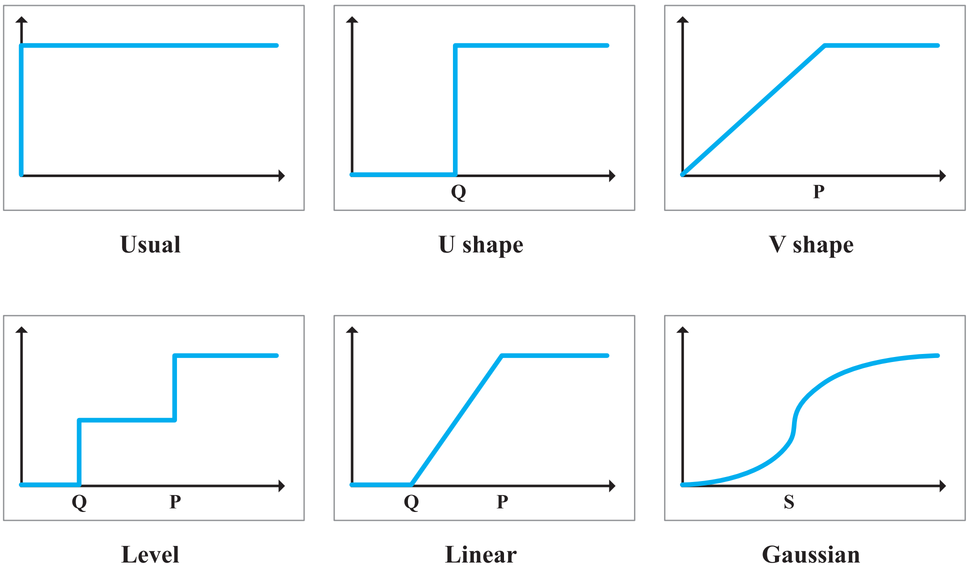
For PROMETHEE, the decision maker uses one of the following 6 functions to represent the preference of an alternative a over another alternative b with respect to criterion i. <Table 1> shows these functions and corresponding mathematical expressions to quantify the preference between two alternatives a and b. The parameters q and p in the last column are indifference and strict preference thresholds for a specific criterion i. To select the proper preference function for the criterion, some guideline is described as follows. The Usual and Level functions are well suited for qualitative criteria such as yes/no or 1-10 point scale. The V and Linear functions are good for quantitative criteria such as profit, monetary loss, cost, etc. U function is a special case of level function. And the Gaussian function is less used due to the difficulty in shape and choice of parameter. The <Figure 1> shows the graphs of 6 types of preference functions.

14) Tuzkaya(2009).
15) Jati(2010).
16) Eshlaghy et.al(2011).

<Table 1> Preference functions and expressions

Preference function	Mathematical expression	Parameter
Usual	$P_i(a,b) = \begin{cases} 0, if\, d(a,b) \le 0, \\ 1, if\, d(a,b) > 0. \end{cases}$	-
U shape	$P_i(a,b) = \begin{cases} 0, if\, d(a,b) \le q, \\ 1, if\, d(a,b) > q. \end{cases}$	q
V shape	$P_i(a,b) = \begin{cases} \frac{d_{(a,b)}}{p} if\ 0 < d_{(a,b)} \le p \\ 1, if\, d_{(a,b)} > p \end{cases}$	p
Level	$P_i(a,b) = \begin{cases} 0, if\ 0 < d_{(a,b)} \le q \\ 0.5, if\, q < d_{(a,b)} \le p \\ 1, if\, d_{(a,b)} > p \end{cases}$	q, p
Linear	$P_i(a,b) = \begin{cases} 0, if\ 0 < d_{(a,b)} \le q \\ \frac{d_{(a,b)} - q}{p - q}, if\, q < d_{(a,b)} \le p \\ 1, if\, d_{(a,b)} > p \end{cases}$	q, p
Gaussian	$P_i(a,b) = 1 - \exp(-\frac{d^2{}_{(a,b)}}{2s^2})$	s

<Figure 1> Graphs of preference functions



For any two alternatives a and b of a finite set A, di(a,b) shows the difference of the value between two alternatives a and b with criterion i and Pi(a,b) is a preference function translating the degree of preference of a to b with criterion i into a value ranging from 0 to 1. If Pi(a,b) > 0, alternative a is better in preference than b, and Pi(a,b)=0, otherwise. The bigger the value Pi(a,b), the more preferred to b. When there are multiple criteria, using the weight Wi for criterion i, the aggregated preference indicator is defined as follows :

$$\prod(a,b) = \sum_{i=1}^{\hbar} P_i(a,b) W_i l \sum_{i=1}^{\hbar} W_i \tag{1}$$

The sum of the Π(a,b) with respect to all other alternatives b∈A is used as a measure of the overall preference of the alternative a and called the leaving flow denoted by $\Phi^+(a)$, which is a measure of the outranking character of a. The higher the value of $\Phi^+(a)$, the better the alternative a and $\Phi^+(a)$ is obtained in the equation (2) below.

$$\Phi^+(a) = \frac{1}{n-1} \sum_{b \in A} \prod(a,b), (a \neq b) \tag{2}$$

Another measure for the non-preference of the alternative a∈A is entering flow denoted by $\Phi^-(a)$, which is the outranked character of alternative a and given in equation (3). The smaller the $\Phi^-(a)$, the better the alternative a.

$$\Phi^-(a) = \frac{1}{n-1} \sum_{b \in A} \prod(a,b), (a \neq b) \tag{3}$$

Along with the equations (1)-(3), the ranking of alternatives is obtained for PROMETHEE method. In principle, the ranking can be calculated based upon two ways: PROMETHEE I and PROMETHEE II.

PROMETHEE I provides partial ranking of alternatives by comparing the leaving and entering flows and in some cases, where ranking may not be clearly ordered. The following rules are used for outranking comparison in PROMETHEE I :

(i) Alternative a is superior to b if one of the equations (4)-(6) holds

$$\Phi^+(a) > \Phi^+(b) \quad and \quad \Phi^-(a) < \Phi^-(b) \tag{4}$$

$$\Phi^+(a) > \Phi^+(b) \quad and \quad \Phi^-(a) = \Phi^-(b) \tag{5}$$

$$\Phi^+(a) = \Phi^+(b) \quad and \quad \Phi^-(a) < \Phi^-(b) \tag{6}$$

(ii) Alternatives a and b are incomparable if one of the equations (7)-(8) holds

$$\Phi^+(a) > \Phi^+(b) \quad and \quad \Phi^-(a) > \Phi^-(b) \tag{7}$$

$$\Phi^+(a) < \Phi^+(b) \quad and \quad \Phi^-(a) < \Phi^-(b) \tag{8}$$

(iii) Alternatives a and b are indifference(same preference) if the equation (9) holds

$$\Phi^+(a) = \Phi^+(b) \quad and \quad \Phi^-(a) = \Phi^-(b) \tag{9}$$

With the PROMETHEE I according to the above rules one might come up with the alternatives not comparable to each other as well as complete outranking of alternatives. However, if complete order among alternatives from the first to the last is required, the net flows(Φ(a)) between leaving and entering flows can be used as another way to rank the alternatives, which is called PROMETHEE II and given in the equation (10). The larger the Φ(a), the better the alternative a.

$$\Phi^+(a) = \Phi^+(a) - \Phi^-(a) \tag{10}$$

III. Efficiency of 19 European Ports

In the study, we consider top 19 container ports in Europe, where the Rotterdam has been ranked 1st during the period 2005-2010 in annual throughput (TEU) while other ports have been changed over the years in rank. The Antwerp and Hamburg ports were scored 2nd and 3rd, respectively in the year 2010(See Appendix 1).

For most commonly used input and output variables to evaluate productivity, Hanh and Rankine[17)] suggested workforce productivity, quay crane productivity, berth productivity, yard productivity, gate productivity, and gang productivity among others. Since, the productivity of a container port is influenced by internal and external factors and their reliability of data, based on Hanh and Rankine, we selected the 4 input variables, i.e., length of berths, terminal area, number of cranes, and average working hours, and 1 output variable, i.e., throughput in calculating productivity, which is in turn used as criteria for evaluation of efficiency of ports for PROMETHEE.

The productivity of an input variable i (P_i) is defined as

$$P_i = \frac{Y}{X_i}, i = 1,\ldots,n \tag{11}$$

whereY = throughput(TEU) per year and X_i = input variable i.

The <Table 2> shows the productivity criteria used for port ranking assessment.

<Table 2> Productivity measures of container port

Input variable(Xi)	Output variable (Y)	Productivity(Pi)
Number of crane	Throughput(TEU)	TEUs/year per crane
Length of berth		TEUs/year per length(m)
Terminal area		TEUs/year per area(m²)
Working hours		TEUs/year per hour

17) Hanh(2006) ; Rankine(2003).

The determination of suitable preference function and corresponding parameters for each criterion is, in real situation applications, very difficult and moreover few studies have been done on port outranking with PROMETHEE. To get around this difficulty, we adopted the equations (12)-(14) from Athawale, et al[18)] and Jati[19)] to normalize the values of productivity criteria and calculate the preference functions as follows:

$$R_{ai} = \frac{X_{ai} - Min(X_{ai})}{Max(X_{ai}) - Min(X_{ai})} \qquad \text{(i = 1, 2,…,K; aA)} \quad (12)$$

$$P_i(a,b) = 0 \, if \, R_{ai} \le R_{bi} \qquad (13)$$

$$P_i(a,b) = (R_{ai} - R_{bi}) \, if \, R_{ai} > R_{bi} \qquad (14)$$

where, X_{ai} is the value of alternative a with respect to criterion i.

The following <Table 3> represents the input and out variables for productivity, where for simplicity, we just consider the year 2010 for the analysis. The results for 2005-2009 are summarized in <Table 8>. For input variables, Rotterdam was ranked 1st in berth length, and cranes while Antwerp was the 1st in terminal area and working hours. The first top three ports (Rotterdam, Antwerp, Hamburg) significantly overcome the other ports in 3 input variables except in working hours. The London port (18th in throughput in 2010) has been counted out in the analysis for the reliable input variables were not available and consequently 19 ports are considered for outranking.

With equations (11)-(12) and <Table 3>, the productivity criteria and their normalized form are shown in <Table 4>. The Southampton port was ranked 1st in productivity for berth length, Laspeziawas for terminal area, Rotterdam for working hours, and Barcelona for cranes, respectively.

Using equations (1) and (13)-(14) the preference of a port over the others is shown in <Table 5>, where, for example, Rotterdam port is preferred 0.163 to Antwerp and 0.127 to Hamburg port. Antwerp, on the other hand, has preference over neither Rotterdam nor Hamburg. The Hamburg is preferred to Rotterdam by 0.041 and Antwerp by 0.077. Similar interpretation can be applied for other ports.

18) Athawale et.al(2010).

19) Jati(2011).

< Table 3> Input and output variables of ports for productivity

			Input				Output
Port number	Ports	Country	Length of berths (m)	Terminal area (m^2)	Hours of working (week)	C/C	2010 (TEU)
1	Rotterdam	Netherlands	16,125	6,854,600	139	118	11,145,804
2	Antwerp	Belgium	13,120	7,654,073	168	93	8,468,475
3	Hamburg	Germany	9,148	5,928,550	153	87	7,895,736
4	Bremerhaven/Bremen	Germany	5,260	2,637,500	147	51	4,888,655
5	Valencia	Spain	4,453	1,481,900	168	36	4,206,937
6	Felixstowe	UK	3,332	1,525,400	168	31	3,400,000
7	GioiaTauro	Italy	3,155	1,300,000	168	16	2,851,261
8	Bahia de Algeciras	Spain	5,594	1,105,305	168	30	2,806,884
9	Zeebrugge	Belgium	8,235	3,067,000	168	20	2,499,756
10	Marsaxlokk	Malta	2,646	1,360,000	168	23	2,370,729
11	Le Harve	France	6,405	2,237,500	168	37	2,358,077
12	St-Petersburg	Russia	2,393	1,264,500	168	24	1,931,382
13	Southampton	UK	1,305	862,000	168	12	1,617,000
14	Barcelona	Spain	4,498	1,046,800	168	9	1,931,033
15	Ambarli	Turkey	3,590	819,811	168	41	1,312,000
16	La spezia	Italy	1,899	432,000	168	15	1,285,155
17	Genoa	Italy	9,520	4,687,293	132	36	1,758,858
18	Constantza	Romania	1,760	690,000	168	19	556,694
19	Billbao	Spain	1,500	493,000	60	9	531,457

<Table 4> Productivity and normalized form

	Ports	Country	Productivity(2010)				Normalized productivity(2010)			
			Length of berths (m)	Terminal area	Hours of working	C/C	Length ofberths	Terminal area	Hours of working	C/C
1	Rotterdam	Netherlands	691.213	1.626	1542.032	94455.966	0.480	0.481	1.000	0.352
2	Antwerp	Belgium	645.463	1.106	969.377	91058.871	0.437	0.281	0.610	0.333
3	Hamburg	Germany	863.111	1.332	992.426	90755.586	0.643	0.368	0.626	0.332
4	Bremerhaven/Bremen	Germany	929.402	1.854	639.541	95855.980	0.706	0.569	0.389	0.359
5	Valencia	Spain	944.742	2.839	481.563	116859.361	0.721	0.948	0.282	0.473
6	Felixstowe	UK	1020.408	2.229	389.194	109677.419	0.793	0.713	0.219	0.434
7	GioiaTauro	Italy	903.728	2.193	326.380	178203.813	0.682	0.699	0.177	0.804
8	Bahia de Algeciras	Spain	501.767	2.539	321.301	93562.800	0.301	0.833	0.174	0.347
9	Zeebrugge	Belgium	303.553	0.815	286.144	124987.800	0.113	0.169	0.150	0.517
10	Marsaxlokk	Malta	895.967	1.743	271.375	103075.174	0.675	0.526	0.140	0.398
11	Le Harve	France	368.162	1.054	269.926	63731.811	0.174	0.261	0.139	0.186
12	St-Petersburg	Russia	807.097	1.527	221.083	80474.250	0.590	0.443	0.106	0.276
13	Southampton	UK	1239.080	1.876	185.096	134750.000	1.000	0.577	0.082	0.569
14	Barcelona	Spain	429.309	1.845	221.043	214559.222	0.232	0.565	0.106	1.000
15	Ambarli	Turkey	365.460	1.600	150.183	32000.000	0.171	0.471	0.058	0.015
16	La spezia	Italy	676.754	2.975	147.110	85677.000	0.467	1.000	0.056	0.304
17	Genoa	Italy	184.754	0.375	256.244	48857.167	0.000	0.000	0.130	0.106
18	Constantza	Romania	316.303	0.807	63.724	29299.684	0.125	0.166	0.000	0.000
19	Billbao	Spain	354.305	1.078	170.338	59050.778	0.161	0.270	0.072	0.161

< Table 5> Overall preference of each port to others

Ports	Rotterdam	Antwerp	Hamburg	Bremen	Valencia	Felixstowe	GioiaTauro	Bahia de Algeciras	Zeebrugge	Marsaxlokk	Le Harve	St-Petersburg	Southampton	Barcelona	Ambarli	La spezia	Genoa	Constantza	Billbao
Rotterdam	-	0.163	0.127	0.153	0.180	0.195	0.206	0.253	0.382	0.215	0.388	0.252	0.230	0.286	0.399	0.251	0.519	0.506	0.412
Antwerp	0.000	-	0.000	0.055	0.082	0.098	0.108	0.143	0.224	0.118	0.226	0.140	0.132	0.177	0.284	0.146	0.357	0.343	0.250
Hamburg	0.041	0.077	-	0.059	0.086	0.102	0.112	0.199	0.301	0.122	0.302	0.157	0.136	0.233	0.339	0.194	0.434	0.420	0.326
Bremerhaven	0.080	0.146	0.073	-	0.027	0.042	0.059	0.158	0.308	0.081	0.316	0.152	0.077	0.190	0.327	0.157	0.447	0.433	0.340
Valencia	0.207	0.272	0.200	0.127	-	0.084	0.098	0.192	0.380	0.171	0.416	0.252	0.143	0.262	0.427	0.162	0.547	0.533	0.440
Felixstowe	0.157	0.222	0.149	0.076	0.018	-	0.042	0.156	0.323	0.105	0.350	0.186	0.068	0.205	0.361	0.155	0.481	0.467	0.374
GioiaTauro	0.218	0.283	0.210	0.144	0.083	0.092	-	0.210	0.353	0.156	0.401	0.237	0.113	0.164	0.412	0.209	0.532	0.518	0.425
Bahia de Algeciras	0.088	0.141	0.120	0.066	0.000	0.030	0.033	-	0.219	0.085	0.223	0.132	0.087	0.101	0.235	0.040	0.355	0.341	0.248
Zeebrugge	0.041	0.046	0.046	0.039	0.011	0.021	0.000	0.042	-	0.032	0.085	0.071	0.017	0.011	0.148	0.076	0.178	0.167	0.108
Marsaxlokk	0.071	0.137	0.064	0.010	0.000	0.000	0.000	0.106	0.230	-	0.245	0.081	0.015	0.119	0.256	0.096	0.376	0.362	0.269
Le Harve	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.038	0.000	-	0.008	0.014	0.008	0.064	0.021	0.131	0.117	0.026
St-Petersburg	0.027	0.079	0.019	0.000	0.000	0.000	0.000	0.072	0.188	0.000	0.172	-	0.006	0.090	0.182	0.043	0.301	0.281	0.188
Southampton	0.208	0.274	0.201	0.128	0.094	0.086	0.080	0.230	0.337	0.137	0.381	0.209	-	0.195	0.378	0.206	0.510	0.484	0.391
Barcelona	0.183	0.238	0.216	0.160	0.132	0.142	0.049	0.163	0.250	0.160	0.294	0.211	0.114	-	0.297	0.186	0.423	0.403	0.310
Ambarli	0.000	0.048	0.026	0.000	0.000	0.000	0.000	0.000	0.090	0.000	0.053	0.007	0.000	0.000	-	0.001	0.161	0.106	0.053
La spezia	0.130	0.187	0.158	0.108	0.013	0.072	0.075	0.083	0.296	0.118	0.288	0.146	0.106	0.167	0.278	-	0.416	0.384	0.295
Genoa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.006	0.012	0.006	0.041	0.018	-	0.059	0.015
Constantza	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.073	-	0.000
Billbao	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.037	0.000	0.002	0.000	0.000	0.000	0.040	0.004	0.122	0.093	-

With equations (2)-(3) and <Table 5> the leaving flow and entering flow of each port is summarized in <Table 6>.

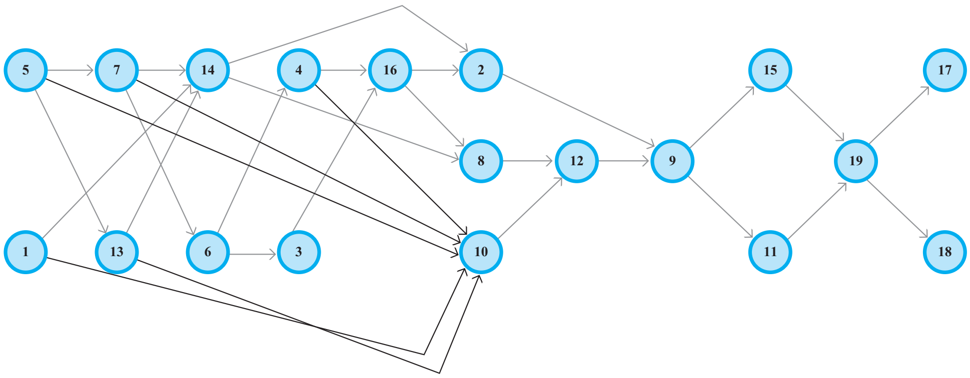
< Table 6> Leaving and entering flow for each port

Port number	Ports	Φ^+(leaving flow)	Φ^-(entering flow)
1	Rotterdam	0.284	0.081
2	Antwerp	0.160	0.128
3	Hamburg	0.202	0.089
4	Bremerhaven/Bremen	0.190	0.063
5	Valencia	0.273	0.040
6	Felixstowe	0.216	0.053
7	GioiaTauro	0.264	0.048
8	Bahia de Algeciras	0.141	0.112
9	Zeebrugge	0.063	0.220
10	Marsaxlokk	0.135	0.083
11	Le Harve	0.024	0.230
12	St-Petersburg	0.092	0.125
13	Southampton	0.252	0.070
14	Barcelona	0.218	0.123
15	Ambarli	0.030	0.248
16	La spezia	0.185	0.109
17	Genoa	0.009	0.353
18	Constantza	0.004	0.334
19	Billbao	0.017	0.248

Equations (4)-(9) and <Table 6> are applied to identify the efficiency of ports using PROMETHEE I and the partial order is shown in <Figure 2> below. Without loss of generality, the port names are represented by numbers inside the circle.

The Rotterdam (1) and Valencia (5) are incomparable to each other, for Φ^+ and Φ^- f Rotterdam are greater than those of Valencia. Also, Valencia(5) is preferred to GioiaTauro(7) and Southampton(13),whereas, Rotterdam(1) outranked Barcelona (14) in preference. Genoa(17) and Constantza(18) are ranked the last with no preference to each other. The other ports are similarly interpreted.

<Figure 2> Partial order with PROMETHEE I



To further classify the order of preference using PROMETHEE II, equation (10) was employed based on which the net flow and complete order were presented in <Table 7>.

< Table 7> Net flow and complete ranking of ports

Port number	Ports	Φ	Rank in productivity	Changes in rank
1	Rotterdam	0.204	3	-2
2	Antwerp	0.032	11	-9
3	Hamburg	0.113	7	-4
4	Bremerhaven/Bremen	0.127	6	-2
5	Valencia	0.233	1	+4
6	Felixstowe	0.163	5	+1
7	GioiaTauro	0.216	2	+5
8	Bahia de Algeciras	0.030	12	-4
9	Zeebrugge	-0.157	14	-5
10	Marsaxlokk	0.052	10	0
11	Le Harve	-0.206	15	-4
12	St-Petersburg	-0.033	13	-1
13	Southampton	0.181	4	+9
14	Barcelona	0.095	8	+6
15	Ambarli	-0.218	16	0
16	La spezia	0.075	9	+8
17	Genoa	-0.345	19	-4
18	Constantza	-0.330	18	0
19	Billbao	-0.232	17	+2

Rotterdam port, 1st in throughput, is now ranked 3rd and the Antwerp, 2nd in throughput is the 11th showing the biggest downgrade among the ports in ranking, while Valencia is the 1st in the productivity point of view and Southampton port is in 4th position taking the biggest leap forward in ranking. The reason for Antwerp is thought to be the relatively low productivity in terminal area compared to other ports and for Southampton the highest productivity in berth length might well explain the increase in ranking. The 4th column shows complete ranking of the ports in preference order, where the incomparable pairs are all ranked according to the values of net flow.

For the rankings of ports over the 2005-2009 period, similar arguments using the same equations applied based on which the ranking of ports are summarized in <Table 8>.

<Table 8> Overall rankings of ports over the period 2005-2010

Port number	Ports	2005	2006	2007	2008	2009	2010
1	Rotterdam	3	4	5	5	3	3
2	Antwerp	10	10	10	10	11	11
3	Hamburg	2	1	2	2	9	7
4	Bremerhaven /Bremen	8	8	8	4	5	6
5	Valencia	11	11	11	8	2	1
6	Felixstowe	7	7	7	9	4	5
7	GioiaTauro	1	2	1	1	1	2
8	Bahia de Algeciras	5	6	6	7	7	12
9	Zeebrugge	18	18	18	17	14	14
10	Marsaxlokk	12	14	15	13	10	10
11	Le Harve	16	16	16	16	16	15
12	St-Petersburg	13	13	13	15	15	13
13	Southampton	6	5	4	6	6	4
14	Barcelona	4	3	3	3	8	8
15	Ambarli	15	15	14	12	13	16
16	La spezia	9	9	9	11	12	9
17	Genoa	19	19	19	19	19	19
18	Constantza	14	12	12	14	18	18
19	Billbao	17	17	17	18	17	17

The results obtained from the PROMETHEE provide some suggestions for the improvement of productivity of ports. For simplicity, the 3 most efficient ports(Rotterdam, Valencia, GioiaTauro) in 2010 are taken for discussion.

The Rotterdam, ranked 3rd in overall productivity, has the most productive working hours compared to other ports whereas the other 3 criteria have less than 0.5 points in normalized scale representing the lower utilization than other ports. Especially, the container crane criterion shows the lowest productivity among the top 3 ports.

Valencia, ranked 1st, on the other hand, has 2 criteria (berth, area) with the highest productivity among the 3 ports but relatively longer working hours considering the throughput.

GioiaTauro, ranked 2nd, shows 69% or higher in 3 criteria(berth, area, crane) with the highest crane productivity among the 3 ports, whereas the working hours, like in Valencia, is only 18% of productivity.

Based on the comparison among ports, Rotterdam needs to take some measure to utilize the crane in more efficient way, while Valencia, and GioiaTauro require more flexible working hours in the direction of reducing the overall working hours.

IV. Conclusion

The shipping industry and the transportation of goods through ports have been rapidly growing owing to global economy, containerization of different types of goods, state of the art ship construction technology, and efficient logistics networks. As a nation's major infrastructure for international trade, port has become important in its role as a connecting point between land and sea transportation.

Also, for faster and efficient transportation, the role of ports has been increasingly important in logistics. Especially, the containerization of goods is a crucial factor in the loading/unloading process as well as in the transportation and consequently, the significance of the container port and its production capabilities requires more improvement to maintain competitive edge over other ports.

As the demand for international trade and global logistic services continues to increase, substantial investments and improvements in both physical capacity and operational efficiencies are necessary to enhance terminal productivity. To meet growing demand, ports need to enhance capacity.[20)]

In this regard, we, unlike other researches using DEA for efficiency, employed the productivity criteria and calculated the efficiency of 19 top European ports through the PROMETHEE method.

For productivity, berth length, number of cranes, working hours, and container area were considered as input variables, and throughput in TEUs was used as output variable.

The results provide another view to assess the efficiency of ports compared with more general and traditional ways, i.e., efficiency with DEA or throughput in TEUS. With the new approach, the decision maker of port operator could selectively(depending on the investment priority, facility expansion, and other port development plans) figure out the specific input variable(s) to be first improved for overall enhancement of port capability.

In the study, we used the common productivity measures for outranking of ports, but more variables(i.e., service quality, cost, waiting time, and other qualitative factors) need to be considered for further research to make the results more fruitful and reliable.*

20) Hanh(2006).

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< Appendix 1>

The following table shows 19 ports with throughput in TUEs for the period 2005-2010

Ports	Country	2010 (TEU)	2009	2008	2007	2006	2005
Rotterdam	Netherlands	11,145,804	9,743,000	10,784,000	10,791,000	9,654,000	9,288,000
Antwerp	Belgium	8,468,475	7,310,000	8,663,000	8,176,000	7,018,000	6,488,000
Hamburg	Germany	7,895,736	7,008,000	9,737,000	9,890,000	8,862,000	8,088,000
Bremerhaven/ Bremen	Germany	4,888,655	4,579,000	5,448,000	4,892,000	4,444,000	3,744,000
Valencia	Spain	4,206,937	3,654,000	3,602,000	3,043,000	2,612,000	2,410,000
Felixstowe	UK	3,400,000	3,100,000	3,200,000	3,300,000	3,000,000	2,700,000
GioiaTauro	Italy	2,851,261	2,857,000	3,468,000	3,445,000	2,938,000	3,209,000
Bahia de Algeciras	Spain	2,806,884	3,043,000	3,324,000	3,414,000	3,257,000	3,179,000
Zeebrugge	Belgium	2,499,756	2,328,000	2,210,000	2,020,000	1,653,000	1,408,000
Marsaxlokk	Malta	2,370,729	2,330,000	2,300,000	1,887,000	1,485,000	1,321,000
Le Harve	France	2,358,077	2,241,000	2,450,000	2,638,000	2,137,000	2,058,000
St-Petersburg	Russia	1,931,382	1,340,000	1,983,000	1,970,000	1,450,000	1,121,000
Southampton	UK	1,617,000	1,400,000	1,710,000	1,900,000	1,500,000	1,374,000
Barcelona	Spain	1,931,033	1,800,000	2,569,000	2,610,000	2,318,000	2,071,000
Ambarli	Turkey	1,312,000	1,836,000	2,262,000	1,940,000	1,446,000	1,186,000
La spezia	Italy	1,285,155	1,046,000	1,246,000	1,187,000	1,137,000	1,024,000
Genoa	Italy	1,758,858	1,534,000	1,767,000	1,855,000	1,657,000	1,625,000
Constantza	Romania	556,694	584,000	1,359,000	1,411,000	1,018,000	771,000
Billbao	Spain	531,457	443,000	557,000	555,000	523,000	504,000

Source: Containerization year book 2011